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Effects of water deprivation on schedule-induced polydipsia*

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Twelve food-deprived male albino rats, randomly assigned to three equal groups, were successively exposed to (a) baseline conditions with water freely available in both the experimental chamber and the home cage, and (b) baseline and free-reinforcement schedule (FFI-60-sec) conditions with water freely available in the experimental chamber and available on a free or limited basis in the home cage. Prior to experimental sessions, Group 1 had continuous access to water in the home cage, whereas Groups 2 and 3 were 12 and 22.33 h water deprived, respectively. Results indicated that water deprivation (a) increased the probability of the development of schedule-induced polydipsia, but (b) had no augmentative effect on either asymptotic intake level or rate of development of the phenomenon.

Although food deprivation normally produces hypodipsia in rats (Calvin & Behan, 1954), Falk (1961) has introduced an ingenuous experimental procedure for inducing marked polydipsia in such animals. Specifically, rats maintained at 90% or less of their free-feeding weights ingest inordinate quantities of water during exposures to certain schedules of intermittent food reinforcement. Although a prodigious amount of research has been conducted on this phenomenon, known as schedule-induced polydipsia (SIP), the precise determinants of its development and maintenance still remain unidentified.

The present experiment was designed to investigate the thirst-produced explanations of SIP (e.g., Teitelbaum, 1966) by assessing the effects of water deprivation on schedule-induced water intakes. If SIP results from postprandial thirst factors, dehydration of the animal prior to schedule exposure should augment both the developmental rate and asymptotic level of the phenomenon, since a more rapid and greater intake of water would be required to facilitate the consumption and digestion of food and to return the animal to homeostatic body fluid conditions. In the present experiment, rats deprived of water for 0, 12, or 22.33 h were exposed to a free-reinforcement schedule which is known to induce polydipsia.

METHOD

Subjects

The Ss were 12 experimentally naive Sprague-Dawley male albino rats approximately 120 days old at the start of the experiment. The Ss, randomly assigned to three equal groups, were maintained at 80% of their free-feeding weights throughout the experiment.

Apparatus

Four Lehigh Valley Electronics experimental chambers (Model 132-02), modified by the removal of the right lever to allow for the insertion of a drinking tube spout, were used. The tip of the drinking spout was slightly recessed behind a plastic positioning collar and located 7 cm to the right of the food magazine and 3.5 cm from the floor of the chamber. Deliveries of Noyes 45-mg "sugarless" pellets were automatically programmed by standard relay circuitry; licks and pellet deliveries were recorded on cumulative recorders, counters, and an Esterline-Angus digital operations recorder.

Procedure

Prior to the initiation of test chamber sessions, each S's water intakes in the home cage were measured at the same time daily under conditions of (1) unrestricted access to food, and (2) food deprivation. Each condition remained in effect until water intakes had stabilized.

The experiment proper consisted of five phases: (1) Baseline 1; (2) Baseline 2; (3) FFI-60-sec condition; (4) reinstatement of Baseline 2; and (5) reinstatement of Baseline 1. All test chamber sessions in each phase were 100 min in duration with water freely available to the Ss.

During Baseline 1 and Baseline 2, test chamber sessions consisted of 100 food pellets placed in the food magazine with the empty feeder operative on a free-fixed interval schedule (FFI 60 sec). Water was freely available to all three groups of Ss in their home cages during Baseline 1. During Baseline 2, water was still freely available to Group 1 in their home cages; however, Group 2 was deprived of water for 12 h immediately prior to each daily chamber session, and Group 3 was completely deprived of water in their home cages (22.33-h water deprivation).

During the FFI-60-sec condition, the home-cage water conditions of Baseline 2 remained in effect, while the daily test chamber sessions consisted of 100 pellets delivered individually and noncontingently at 60-sec intervals to each S (FFI-60-sec schedule).

During the reinstatements of Baseline 2 and Baseline 1, the chamber session and home-cage conditions previously employed in Baseline 2 and Baseline 1 were, respectively, replicated.

Home cage and test chamber intakes were measured daily by weight difference in the water bottle and converted into milliliters. Each phase of the experiment proper remained in effect until test chamber water intakes had stabilized. Stability was defined as a less than 25% variance of the difference between the total intakes for the last three sessions and the previous three sessions from the total of the last six sessions for each S.

RESULTS AND DISCUSSION

Mean group water intakes obtained in (a) the home

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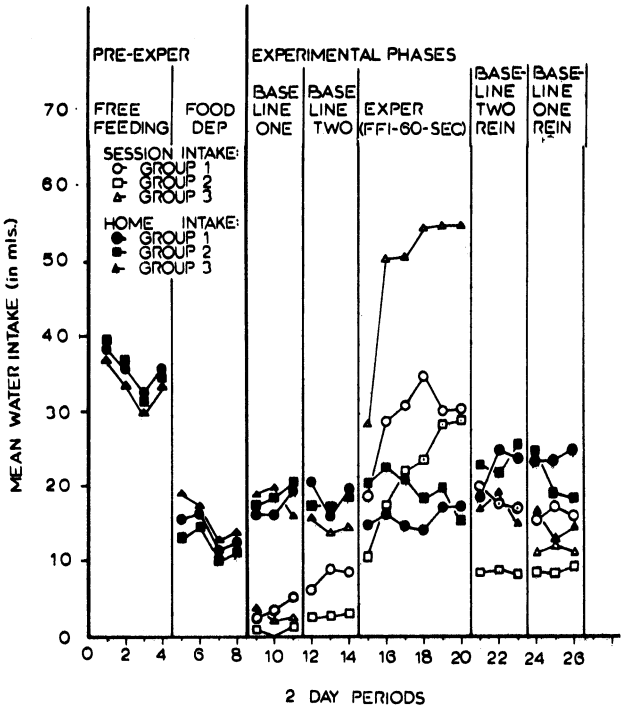

Fig. 1. Mean group water intakes obtained in the home cage and test chamber during all preexperimental and experimental phases.

cage during preexperimental, free-feeding, and food-deprivation conditions and during all appropriate phases of the experiment, and (b) the test chamber during all phases of the experiment are presented in Fig. 1. Relative to free feeding, food deprivation produced marked decrements in home-cage intakes; during each preexperimental condition, the mean home-cage intakes of the three groups were essentially equivalent. Initiation of test chamber sessions slightly increased home-cage intakes for all three groups, relative to the preceding preexperimental, food-deprivation condition. During the FFI-60-sec condition, the mean home-cage intakes of Groups 1 and 2 were not substantially altered, although previous SIP research (e.g., Falk, 1969) has consistently reported that home-cage intakes decline to dramatically low magnitudes during concurrent SIP conditions in the test chamber.

A comparison across phases of mean group water intakes obtained in the test chamber indicated that (a) relative to Baseline 1, water deprivation in the home cage during Baseline 2 produced marked increases in test chamber water intakes, (b) the FFI-60-sec condition produced polydipsic intakes in the test chamber for all three groups, relative to both preceding baselines, and (c) the mean intake levels obtained in the original Baseline 1 and Baseline 2 conditions were not fully recovered when the baseline conditions were reinstated. A comparison within phases of mean group water intakes obtained in the test chamber indicated that (a) during Baseline 1, the mean intakes of the three groups varied minimally, (b) during Baseline 2, the greatest mean intake occurred in Group 3 (22.33-h water deprivation), followed by Group 1 (0-h water deprivation) and Group 2 (12-h water deprivation), respectively, and (c) the polydipsic intakes produced by the FFI-60-sec condition retained the same group order that was evident in Baseline 2.

Although the mean test chamber intakes presented in Fig. 1 suggest that water deprivation augmented schedule-induced water intakes, these data provide a biased representation of the overall experimental results. Half of the Ss in both Group 1 and Group 2 completely refrained from drinking in the test chamber, thus attenuating their respective group mean intakes. A comparison of individual S's test chamber and home-cage intakes revealed trends which were not evidenced by the mean group intakes. Longer periods of home-cage water deprivation during Baseline 2 generally produced greater increases in test-chamber intakes, relative to shorter periods of water deprivation. All Ss with water intakes in the test chamber during Baseline 1 and/or Baseline 2 developed polydipsic drinking behavior during the FFI-60-sec condition (i.e., test-chamber intakes during the FFI-60-sec condition were at least twice as great as those during both Baseline 1 and Baseline 2); the polydipsic intakes were accompanied by extreme decrements in home-cage intakes. Although there was inter-S variability in peak levels of SIP intakes, these differences were not directly related to the Ss' home-cage water-deprivation conditions.

To clarify the ambiguous differences between groups, several statistical comparisons were made. A repeated measures analysis of variance applied to the test-chamber intakes of all Ss from the last six sessions of each experimental phase indicated that only the difference between experimental phases was significant ($F = 18.48$, $df = 4/36$, $p < .001$). A second repeated measures analysis of variance was applied to the test-chamber intakes of the polydipsic Ss only. The results were congruent with those of the previous statistical analysis; only the difference between phases was significant ($F = 82.43$, $df = 4/20$, $p < .001$). Since these two analyses indicated that home-cage water-deprivation and/or FFI-60-sec schedule conditions produced significant changes in test-chamber water ingestion but had no interactive effect, a new multiple range test (Kirk, 1968) was made on the mean-phase water intakes. The results revealed that (a) the mean intakes of Baseline 2 and its reinstatement were significantly ($p < .01$) greater than only the mean intake of Baseline 1, (b) the mean intake of the FFI-60-sec condition phase was significantly greater ($p < .01$) than the mean intakes of all other experimental phases, and (c) the mean intake of the reinstatement of Baseline 1 was significantly greater ($p < .01$) than only the mean intake of the original Baseline 1. The conclusions drawn from these results included: (a) home-cage water deprivation produced

significant increases in test-chamber intakes, (b) the combined water-deprivation and FFI-60-sec conditions induced polydipsic intakes significantly greater than those produced by water deprivation alone, and (c) while the effects of the FFI-60-sec condition on test-chamber intakes were reversible, the effects of home-cage water deprivation were not.

The effects of water deprivation on the level and development of SIP were assessed by applying a repeated measures analysis of variance to the polydipsic Ss' test-chamber intakes from the 12 sessions of the FFI-60-sec condition. A significant difference between sessions ($F = 11.93$, $df = 11/55$, $p < .001$) demonstrated the gradual development of SIP that has been reported in previous research (cf. King & Schaeffer, 1973). The nonsignificant difference between groups ($F = 0.49$, $df = 2/5$, $p > .05$) indicated that water deprivation had no effect on the quantity of water consumed during SIP, while the nonsignificant interaction between groups and sessions ($F = 0.79$, $df = 22/55$, $p > .05$) indicated that water deprivation had no effect on the rate of development of SIP.

Finally, a repeated measures analysis of variance was applied to the total daily water intakes (i.e., test-chamber plus home-cage intakes) of all Ss from the last 6 days of each preexperimental and experimental phase. The results were similar to those of the analysis made on the test-chamber intakes only. There was a significant difference between phases ($F = 19.29$, $df = 6/54$, $p < .001$); since home-cage intakes were not checked for stability prior to initiation of successive phases, both the difference between days ($F = 6.04$, $df = 5/45$) and the interaction between phases and days ($F = 4.21$, $df = 30/270$) were also statistically significant ($p < .001$). To explore the significant difference between phases, a new multiple range test ($p < .01$) was made on the mean total intakes of the seven phases, providing the following results. A nonsignificant difference between the mean total intakes of Baselines 1 and 2 indicated that, while home-cage water deprivation increased test chamber intakes, it did not increase total daily water intakes. In contrast, the combined water-deprivation and FFI-60-sec conditions produced total daily water intakes which significantly exceeded the total intakes in all other phases, regardless of their feeding and/or water-access conditions. The effects of the FFI-60-sec condition on total water intake per day were reversible, since the mean total intakes of Baseline 2 and its reinstatement were not significantly different.

Since water deprivation augmented neither the asymptotic level nor the developmental rate of SIP, it seems evident that postprandial thirst, acting synergically with either feeding schedules or cellular fluid imbalance, is not sufficient to account for the development or maintenance of schedule-induced drinking. Test-chamber water intakes under the combined intermittent reinforcement-schedule and water-deprivation conditions were greater than those produced by water deprivation alone; similarly, total daily water intakes during the combined conditions were greater than those under only thirst-determining conditions (i.e., free access to food and water, food and water deprivation, and food but not water deprivation). Increased water intakes in the test chamber following periods of water deprivation were compensatory in nature, restoring but not exceeding cellular fluid homeostasis. Schedule-induced water intakes, however, pathologically exceeded those produced by water deprivation and/or attributable to thirst factors, resulting in pathological, total daily water intakes. These results strongly indicate that SIP is not mediated by standard thirst determinants but rather overrides any peripheral control of fluid intake. Supportive data for this conclusion have been provided by Falk (1969), who reported that overhydration of Ss immediately prior to experimental sessions had no attenuating effect on schedule-induced water consumption.

However, the results of the present experiment do not completely refute the role of thirst factors in the specific development of schedule-induced drinking in relation to other possible behaviors, since, in the present experiment, the probability of SIP development was found to be increased by prior thirst-induced drinking during test-chamber sessions. Specifically, King (1971) has concluded, from a series of experiments, that an organism subjected to aversive stimuli will demonstrate increases in the frequency and duration of its most highly probable, available response. Since intermittent reinforcement is aversive to food-deprived animals, water-deprived animals under such conditions should be more likely to display increases in water ingestion (i.e., their most highly probable response) than non-water-deprived animals. In standard SIP experiments with rats not water deprived, drinking would also be the response most likely to increase in frequency and duration due to the strong association of feeding and drinking in rats (Fitzsimons & LeMagnen, 1969). For example, Segal (1969) has reported that rats, given access to water and a running wheel, consistently demonstrate significantly greater increases in drinking than wheel running during intermittent schedule conditions. The increased probability of SIP as a function of water deprivation is also in agreement with the ethological account of the phenomenon offered by Wuttke and Innis (1972). These authors proposed that the thwarting of food consumption inherent in intermittent reinforcement schedules leads to secondary displacement activity. Since topography of the displacement activity is determined in part by the relative action-specific energies of other instincts, water deprivation should increase the probability of the development of polydipsia due to the increased propensity to engage in drinking.

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